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Research Article

Spatial turnover and knowledge gaps for African chelonians mirror those of African small mammals: conservation implications

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Abstract
The causes of spatial distribution gaps for a given species may be either both natural (habitat discontinuities) or non-natural (local extinctions, inaccurate knowledge). These species are defined as 'gap species'. We analyzed the country checklists for African chelonians in order to identify both gap species and gap countries. We also compared patterns observed in chelonians with those observed in African small mammals. Species richness was highest in South Africa, Congo, Nigeria, Tanzania, Angola and Ghana, and the countries exchanging the smallest number of species with neighboring countries were South Africa and Congo. The main gap countries were Togo, Benin, and Congo. Moist savannahs, tropical forests, and swamp areas were inhabited by significantly higher numbers of gap species. Body size of gap species was significantly larger than that of non-gap species, possibly due to bush-meat consumption. Increases in the number of gap species per country were significantly correlated between chelonians and small mammals. There was a significantly positive relationship of turnover rates by paired countries between chelonians and rodents as well as between chelonians and insectivores, and the mean turnover rates by country were highest in Sudan and Chad, whereas the whole southern portion of Africa and part of West Africa had low mean turnover rates. The high number of gap species in Congo, Central African Republic (C.A.R.), and Cameroon may be due to suboptimal research, and in Togo and Benin may depend on the Dahomey Gap. The tropical forests and the moist savannahs are the most important habitats for both groups.

Key words: *Africa; Chelonians; Country prioritization; country lists of species; conservation*

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Introduction

Effective conservation actions for threatened species are mostly assured by country-level governmental organizations [1- 2]; locally-based and non-governmental agencies are much less relevant for political decisions, but often provide background expertise for decision-making [3]. Thus, it is important to have detailed accounts of species occurrences by country, as these data are basic for many conservation actions at multiple levels [3]. Species checklists can also be utilized easily in order to (i) make direct biodiversity comparisons among countries, (ii) evaluate the patterns of turnover of species from one country to a neighboring country [2], and (iii) compare species checklists among countries in order to rank countries according to their conservation value within given geographic contexts [2]. Developing such data is difficult in geographic regions where the information for each country differs considerably, such as in Africa [4].

Production of accurate checklists is complicated by the fact that, especially in tropical and scientifically neglected regions of the world, there is often uneven knowledge about the distribution of various species [5]. The known range of a given species often includes artificial gaps due to inadequate research efforts, as well as natural gaps due to displaced patches of suitable habitats or topographic barriers [4].
Turtles are the most endangered group of vertebrates in the world in terms of the proportion of species classified as threatened according to the International Union for Conservation of Nature (IUCN) Red List [6-7]. In Sub-Saharan Africa, turtles and tortoises are exposed to several threats, including intense hunting for food and traditional medicine, habitat loss, collection for the pet trade, etc. [8-9]; however, global studies analyzing their ecological and biogeographic patterns at the African continent scale and the implications for conservation, have been rarely performed [9-10].

In this study, based on the country-based checklists of chelonians for the whole African continent, we aim to (1) identify the countries with greater taxonomic uniqueness and hence a priority role in global conservation strategies; (2) highlight countries where more research is needed, where distribution gaps are caused by insufficient research rather than on real absences; (3) determine some of the ecological correlates of species with artificial gaps in the distribution range; and (4) compare the observed patterns to those already highlighted in a parallel study on African rodents and insectivores [4], in order to detect any general pattern in these phylogenetically unrelated and ecologically distinct groups of vertebrates.

Methods

For this study, we considered the whole African continent, excluding Madagascar, Seychelles and all Indian Ocean archipelagos. We utilized species data provided by the 'EMYSystem Global Turtle Database' [11]. These data consist of locality records depicted on maps produced by Iverson [12-13] and collected in a web site by the 'Terra Cognita' laboratory at the Geosciences Department of Oregon State University in Corvallis, Oregon. The EMYSystem Global Turtle Database contains distribution records for most of the chelonian species of the world (excluding the sea turtles). In addition, we also considered literature sources reporting distribution data which were not available in the EMYSystem Global Turtle Database (e.g. [8], [14]). For each species, we defined the range of countries of presence. We considered as presences in given countries also those cases in which a species was just marginally found within the geographical borders of that country. We did not consider Djibouti, Lesotho, Gambia, and Swaziland in our analyses because they were pooled within their main surrounding countries (i.e. Djibouti with Somalia, Lesotho and Swaziland with South Africa, and Gambia with Senegal). We excluded Madagascar, Seychelles and all Indian Ocean archipelagos because of their distinct biogeography, not directly comparable with the rest of the continent (e.g., [15]).

Interpretation of African turtle taxonomy is in part controversial. We have chosen to use a single, widely available, recently produced synthesis on all the species of the continent (Branch, 2008). We took into consideration all Sub-Saharan turtle taxa listed in Branch [8], and also compared this literature source with [16]. We considered *Kinixys belliana* as a single species, despite some authors consider the western African populations of this species to belong to a distinct species, *Kinixys nogueyi* (e.g., [17]). Data on body sizes and main habitats are obtained from [8].

We used the same methods as described in [4]. For each country, we created a checklist of its turtle species (Appendix 1), and then we contrasted this checklist with the checklists compiled for each of the neighboring countries. In this way, a list of species shared between a given country and its neighboring countries was compiled.

With the summarized information obtained from the checklists (Appendix 1), we calculated a turnover rate between each pair of countries, using for example the formula:

$$Turnover=(\ \gamma\ diversity/\ \alpha\ diversity)-1;$$

where γ diversity is the total cumulative richness for the two countries, and α diversity is their mean richness. This ranges from 0 (no species turnover between countries) to unity (the country is completely different from its neighbour). For example, according to Appendix 2, Mali has 6 species and Niger 5, and they share 4 species. Thus, γ diversity=7, α diversity=5.5, and the turnover rate is then 0.2727. We also calculated the mean turnover rate per country, which is the arithmetic mean of the turnover values of a given country with its various neighbor countries.

In addition, for each country a list of the endemic species (i.e., those species which occur only in the target country) was also compiled. The relative importance in conservation terms of the various countries was then assessed using both the portion of species shared with each of the neighboring countries and the number of endemic taxa. The conservation value of a given country was considered to be greater if it contained an elevated number of endemic taxa and shared a relatively minor portion of its species with each of the neighbouring countries.

Following [4], we defined as 'gap species' those taxa which exhibit a distribution gap at the country scale. For instance, if a species is found in Morocco and Egypt, our gap countries are therefore Algeria, Tunisia, and Libya. We identified species with presumed distribution gaps by simply comparing the species' distribution by country, and then highlighting the eventual gaps occurring between two or more countries where the species is known to occur. The relative importance of the various gap countries was assessed by counting the total number of gap species occurring in each country.

As in [4], we categorized habitats into seven types: (1) semidesert, (2) dry savannah (including Karoo), (3) open habitat (e.g., shrublands and plantation or agricultural land), (4) moist savannah, (5) Mediterranean shrublands (in both North Africa and South Africa), (6) tropical forest, and (7) swamp areas.

We explored whether the number of gap species per country was dependent on country area (in km^2) by Pearson's correlation coefficient, and the association of gap species with particular habitat types by observed-versus-expected χ^2test. Comparisons between carapace length (mm) of 'gap species' and 'non-gap' species were performed using a Mann-Whitney U-test. All tests were two-tailed, with alpha set at 5%. Analyses were performed with Statistica (STATSOFT 2010, Statistica software, release 11.0; Tulsa, AZ, USA).

Results

Chelonian patterns

The list of the number of species occurring in each African country and the number of species shared by a given country with each of its neighboring countries are given in Appendix 2. The most relevant countries in terms of species richness were South Africa, Congo, Nigeria, Tanzania, Angola and Ghana (Fig. 1). However, the two most important countries which exchanged relatively few species with neighboring countries were South Africa and Congo (Appendix 2). Overall, there were only 8 species endemic to single countries (17% of the total number of species, N = 47): four are found in South Africa, and only one each in Kenya, Gabon, Mozambique, and Namibia.

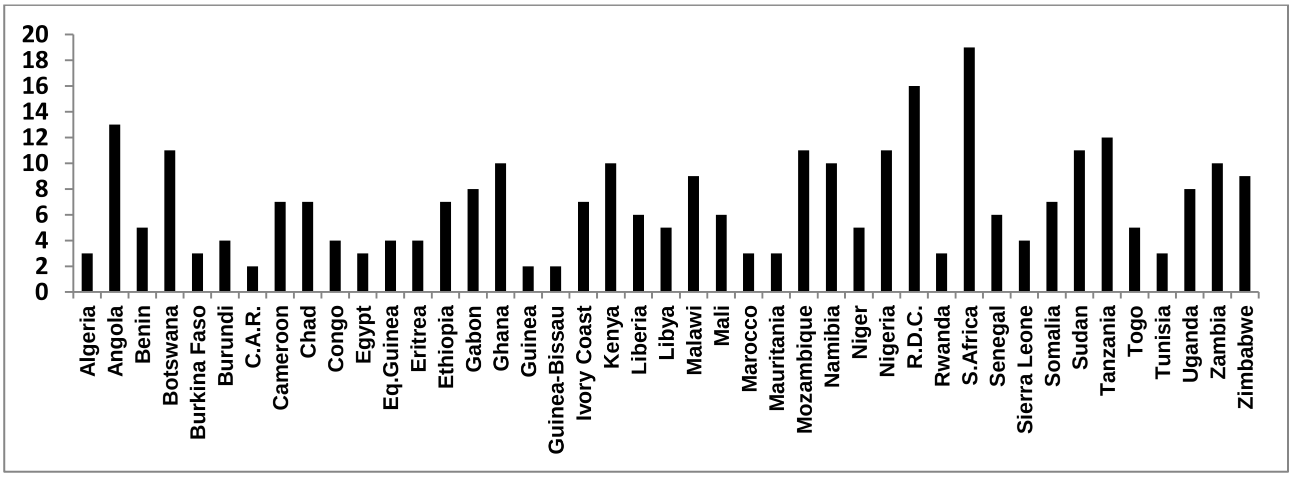

Fig. 1. Species richness of African chelonians across countries.

The number of gap species clearly varied among countries (Fig. 2): the mean number of gap species per country was 1.22 ± 1.62, n = 43, with a range of 0-6. The main gap countries were Togo, Benin, and Congo (Fig. 2). The number of gap species per country tended to decrease with country area (km^2), but the relationship fell just short of statistical significance ($r = -0.288$, $P = 0.052$).

The list of species with observed distribution gaps, including details of their mean body sizes and main habitat, is given in Appendix 3. Considering both terrestrial and aquatic species in the analysis, there was a significant association of gap species with particular habitat types (χ^2=25.84, df =6, P = 0.00023), with moist savannahs, tropical forests, and swamp areas being inhabited by significantly higher numbers of gap species. Repeating the same analysis for only aquatic species (as there were insufficient numbers of terrestrial gap species for analysis), and after deleting habitat type 'swamps' because it is common to all aquatic species, resulted in moist savannahs and tropical forests still housing the higher numbers of gap species (χ^2=16.82, df =4, P = 0.0021). Body size of gap species was significantly larger than that of non-gap species (Mann-Whitney U-test, Z=2.37, U = 103, P = 0.018).

The mean turnover rate for each country varied remarkably among the different African regions (Fig. 3). Highest mean turnover rate scores were observed in Sudan and Chad, whereas the whole southern portion of Africa and part of West Africa revealed low mean turnover rates (Fig. 3).

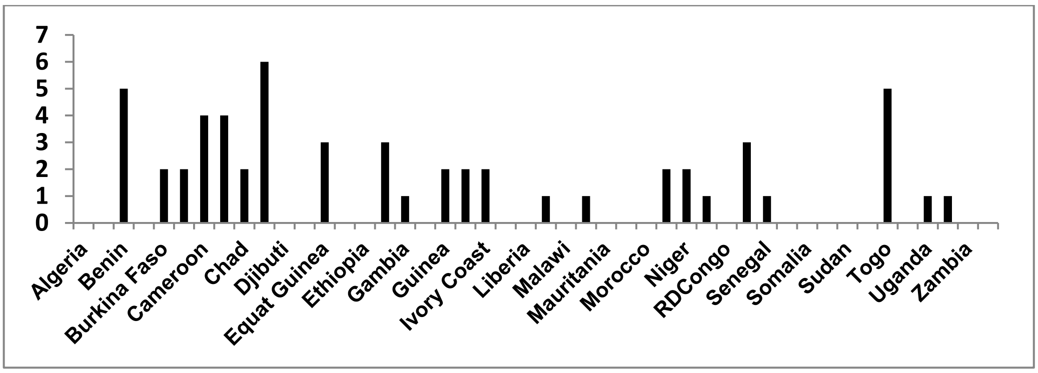

Fig 2. Distribution of gap species across countries. Note that the countries housing the Dahomey Gap (Togo and Benin) provided significantly higher numbers of gap species than the rest of African countries.

Comparisons between chelonians and small mammals

There was a significantly positive relationship of turnover rates by paired countries between chelonians and rodents ($r = 0.354$, $P < 0.0005$) as well as between chelonians and insectivores ($r = 0.258$, $P = 0.013$). An ANCOVA analysis revealed that the two regression lines were different at a marginally significant level ($F = 3.632$, $MS = 0.131 \pm 0.136$, $P = 0.048$) (Fig. 4).

There was a positive association between increases in the number of gap species per country in chelonians and rodents ($r^2 = 0.354$, $P = 0.0001$) as well as in chelonians and insectivores ($r^2 = 0.156$, $P = 0.028$); however,the slope of the regression line relative to the relationship between chelonians and rodents differed significantly from that relative to the relationship between chelonians and insectivores (one-way ANCOVA: $F = 12.23$, $P = 0.0007$).

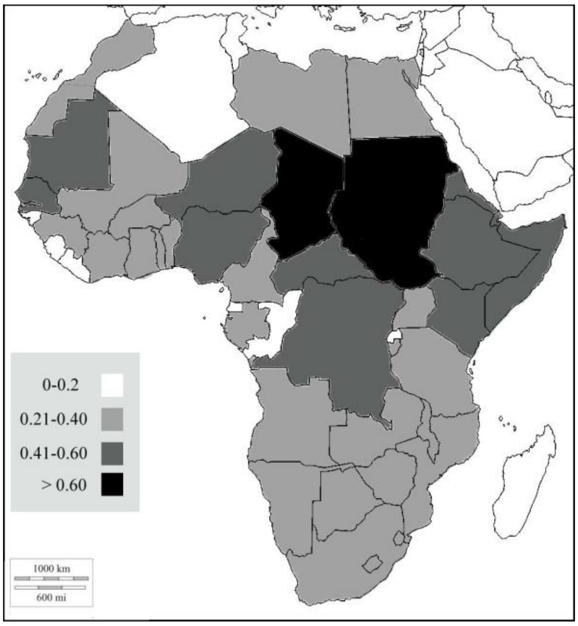

Fig. 3. Map of Africa showing the mean turnover rate for each country considering its neighbors, with grey scale resembling classes of turnover rates.

Discussion

Ranking African countries

Previous studies indicated the countries in the Gulf of Guinea coast, the Guinea-Congo rain forest region, and the Albertine Rift to be the most important areas of the African continent in terms of freshwater turtle species richness [18, 10], whereas South Africa is the most relevant area for the terrestrial species [18]. Our study revealed that, in terms of relative uniqueness (due to lower rates of spatial turnover at country level), some of the Gulf of Guinea countries (i.e. Nigeria and Ghana) still appear very important, as well as Congo and South Africa, thus confirming patterns highlighted by earlier studies with different approaches. There are obvious biogeographic reasons behind these patterns: for instance, South Africa is one of the main centers of endemism of the African continent for both plants and animals [19-20-21]. The same is also true for the Lower Guinean Forest Zones, as they are likely locations of forested refugia during periods of the Pleistocene in which sub-Saharan Africa was significantly more arid than today (e.g. [22-23-24-25-26]). Also Tanzania, which houses part of the Albertine Rift, emerged as an important country in our analysis, the same as in [10]. Tanzania is delimited westerly by the Great Rift Valley, which has been a barrier for the distribution of many taxa (e.g. [27]), likely reducing the number of species shared by Tanzania with their neighboring countries. Indeed, Tanzania also appeared important for country-based turnover rates of rodents and insectivores [4]. The mountains of eastern Tanzania (and southern Kenya), the so called “Eastern Arc,” are an increasingly recognized center of endemism [28-29].

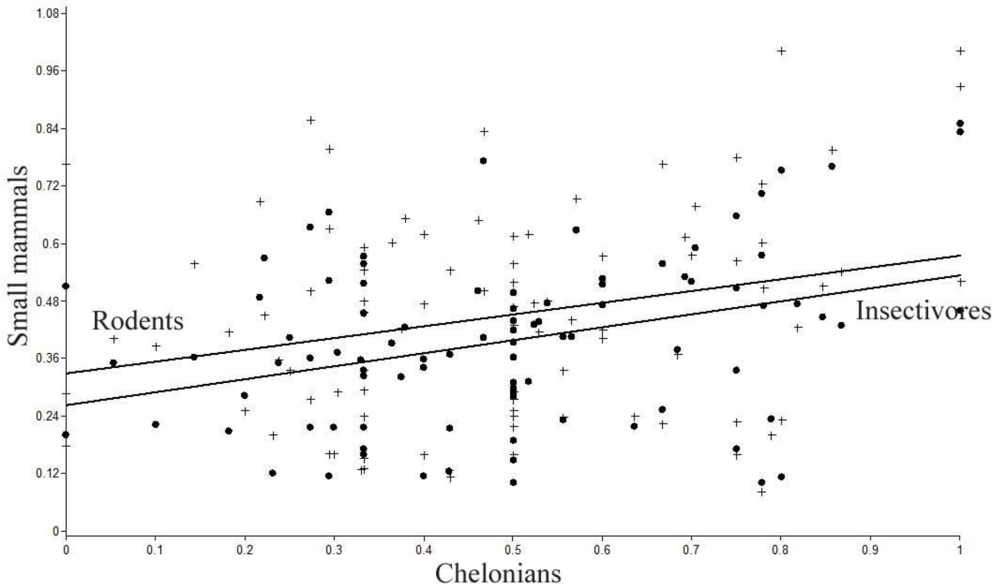

Fig. 4. Relationships of turnover rates by paired countries between chelonians and small mammals (rodents and insectivores). For the statistical details, see the text.

It should also be mentioned that Central African Republic (C.A.R.) is apparently inhabited by only two species, which is highly unlikely given that this is a region of high biodiversity richness for other animal groups [2]. Thus, we think the C.A.R.'s chelonians to be the least known in Africa, and that further baseline studies should be focused in this country.

Species showing distribution gaps, and the gap countries

As pointed out by [4], gaps in species' distribution ranges can be either natural or apparent. Typically, natural distribution gaps occur when species inhabit a habitat type found only in two distant countries and not in between the two countries (e.g., *Kinixys belliana*, see map in [8]), whereas apparent distribution gaps typically occur where species inhabit a spread habitat type, but with insufficient field research performed in part of its range (e.g., *Cyclanorbis elegans* and *Trionyx triunguis*, see map in [8]). In addition, current gaps can be produced by extinctions fragmenting an originally continuous distribution. Among African chelonians, this was clearly the case of *Geochelone sulcata*, the largest of all continental tortoise species, which is now extirpated from Western Sahara and still found in isolated populations from Ethiopia and Sudan eastwards to Senegal [8].

As already seen in the case of rodents and insectivores [4], African chelonians also showed an higher number of gap species in Togo and Benin, as well as in Congo, which was not highlighted as a major gap country by [4]. We interpret these figures distinctly. We consider that, at the actual level of scientific knowledge of African chelonians, there is an absence of country records for Congo, which is rather inhospitable for field-based research. Thus, the high number of gap species in Congo (and also in C.A.R. and Cameroon) may be due to insufficient field research.

Conversely, Togo and Benin, which are among the smallest African countries, are the two main gap countries for chelonians, probably because these countries coincide with the Dahomey Gap, a savanna corridor interrupting the zonal West African rain forest [30]. Hence, the typical rainforest species occurring in southern Nigeria and in Upper Guinean forests do not occur in the savannahs of Togo and Benin (e.g., *Pelusios niger*, a species which is typically found in rivers and creeks crossing the Biafran tropical forests; see [31]).

Our study also showed that gap species were primarily found among the moist savannah and tropical forest dwellers. We consider this to be a direct consequence of heavy rates of habitat loss and fragmentation of moist savannahs (for instance, the Guinea savannah in West Africa) and tropical forests, thus isolating populations of chelonians which were once spread widely throughout these habitat types. Our study suggests that remnant patches of moist savannahs and tropical forests should be priority habitats for the conservation of African chelonians in the years to come.

The fact that gap species are characterized by larger body size than non-gap species can be directly linked to bush-meat consumption (e.g., [32-33]). Indeed, as humans typically select larger species for meat consumption, their hunting activity can more easily impact the natural populations of the larger species, thus causing local extirpations and even larger scale extinctions. Hence, our study indirectly supports the notion that larger turtle species are more prone to extinction than smaller species, as is the case of the giant softshell turtles in Asia [34].

Comparisons between chelonians and small mammals

Our study documented several consistent patterns between chelonians and small mammals. For instance, the various African countries ranked similarly according to our criteria for both chelonians and small mammals, thus highlighting that the same countries may be considered of priority importance for the preservation of these distinct groups of terrestrial vertebrates. In addition, in both groups there was no correlation between country size and number of gap species per country (for the case of rodents and insectivores, see [4]), and the main gap countries were also similar between groups. Indeed, there were significantly positive correlations between increases in the number of gap species per country in chelonians and rodents, and in chelonians and insectivores. In general, in both small mammals and chelonians, the tropical forests (and also the moist savannahs for these latter) emerged as the most important habitats .

Implications for conservation

All the above-presented findings may have profound conservation implications. The most obvious implication is that tropical forest fragmentation is causing the extirpation of many populations of both chelonians and small mammals, and thus conservation efforts at the continental scale should be devised especially to preserve the remaining tropical forests. Our study also documented that Congo, C.A.R., and Cameroon are countries where scientific surveys should be improved in order to explain the apparent distribution gaps of several species. In addition, our study provided a first example of how research on African chelonians can be used to study general ecological and biogeographical patterns of rodents and insectivores, and vice versa. For the future, it would be interesting to add to this type of analyses other groups of non-vertebrate organisms (for instance, butterflies or plants), in order to generalize patterns of country-based species turnover and gap species/countries at the continental scale.

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Appendix 1. Country-based checklists of African chelonians.

ALGERIA
Emys orbicularis, Mauremys leprosa, Testudo graeca.
ANGOLA
Cycloderma aubryi, Geochelone pardalis, Kinixys belliana, Kinixys erosa, Kinixys spekii, Pelomedusa subrufa, Pelusios bechuanicus, Pelusios castaneus, Pelusios gabonensis, Pelusios nanus, Pelusios rhodesianus, Trionyx triunguis, Stigmochelys pardalis.
BENIN
Kinixys belliana, Kinixys erosa, Pelomedusa subrufa, Pelusios castaneus, Trionyx triunguis.
BOTSWANA
Chersina angulata, Geochelone pardalis, Kinixys belliana, Kinixys lobatsiana, Pelomedusa subrufa, Pelusios bechuanicus, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Psammobates oculifera, Stigmochelys pardalis.
BURKINA FASO
Cyclanorbis senegalensis, Kinixys belliana, Pelomedusa subrufa.
BURUNDI
Kinixys belliana, Pelomedusa subrufa, Pelusios rhodesianus, Pelusios subniger.
CAMEROON
Kinixys belliana, Kinixys erosa, Kinixys homeana, Pelomedusa subrufa, Pelusios gabonensis, Pelusios niger, Trionyx triunguis.
C.A.R.
Kinixys erosa, Pelusios gabonensis.
CHAD
Cyclanorbis elegans, Cyclanorbis senegalensis, Geochelone sulcata, Pelomedusa subrufa, Pelusios adansonii, Pelusios gabonensis, Trionyx triunguis.
CONGO
Kinixys erosa, Pelusios carinatus, Pelusios castaneus, Pelusios chapini.
EGYPT
Testudo graeca, Testudo kleinmanni, Trionyx triunguis.
ERITREA
Geochelone sulcata, Kinixys belliana, Pelomedusa subrufa, Trionyx triunguis.
ETHIOPIA
Geochelone pardalis, Geochelone sulcata, Kinixys belliana, Pelomedusa subrufa, Pelusios sinuatus, Trionyx triunguis, Stigmochelys pardalis.
GABON
Cycloderma aubryi, Kinixys erosa, Pelusios carinatus, Pelusios castaneus, Pelusios gabonensis, Pelusios niger, Trionyx triunguis, Pelusios marani.
GHANA
Cyclanorbis elegans, Cyclanorbis senegalensis, Kinixys belliana, Kinixys erosa, Kinixys homeana, Pelomedusa subrufa, Pelusios castaneus, Pelusios cupulatta (= gabonensis), Pelusios niger, Trionyx triunguis.
GUINEA
Kinixys belliana, Pelusios castaneus.
GUINEA-BISSAU
Cyclanorbis senegalensis, Trionyx triunguis.
EQUATORIAL GUINEA
Kinixys erosa, Kinixys homeana, Pelusios niger, Trionyx triunguis.
IVORY COAST
Cyclanorbis senegalensis, Kinixys erosa, Kinixys homeana, Pelomedusa subrufa, Pelusios castaneus, Trionyx triunguis, Pelusios cupulatta.

KENYA

Geochelone pardalis, Kinixys belliana, Malacochersus tornieri, Pelomedusa subrufa, Pelusios castanoides, Pelusios sinuatus, Pelusios williamsi, Pelusios broadleyi, Trionyx triunguis, Stigmochelys pardalis.

LIBERIA

Kinixys erosa, Kinixys homeana, Pelusios castaneus, Pelusios niger, Trionyx triunguis, Pelusios cupulatta.

LIBYA

Mauremys leprosa, Testudo graeca, Testudo hermanni, Testudo kleinmanni, Testudo marginata.

MALAWI

Cycloderma frenatum, Geochelone pardalis, Kinixys belliana, Pelomedusa subrufa, Pelusios castanoides, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Stigmochelys pardalis.

MALI

Cyclanorbis senegalensis, Geochelone sulcata, Kinixys belliana, Mauremys leprosa, Pelomedusa subrufa, Pelusios adansonii.

MOROCCO

Emys orbicularis, Mauremys leprosa, Testudo graeca.

MAURITANIA

Geochelone sulcata, Mauremys leprosa, Trionyx triunguis.

MOZAMBIQUE

Cycloderma frenatum, Geochelone pardalis, Kinixys belliana, Kinixys natalensis, Kinixys spekii, Pelomedusa subrufa, Pelusios castanoides, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Stigmochelys pardalis.

NAMIBIA

Chersina angulata, Geochelone pardalis, Homopus signatus, Homopus bergeri, Pelomedusa subrufa, Pelusios bechuanicus, Psammobates oculifera, Psammobates tentorius, Trionyx triunguis, Stigmochelys pardalis.

NIGER

Geochelone sulcata, Mauremys leprosa, Pelomedusa subrufa, Pelusios adansonii, Trionyx triunguis.

NIGERIA

Cyclanorbis elegans, Cyclanorbis senegalensis, Geochelone sulcata, Kinixys belliana, Kinixys erosa, Kinixys homeana, Pelomedusa subrufa, Pelusios adansonii, Pelusios castaneus, Pelusios niger, Trionyx triunguis.

R.D.C.

Cycloderma aubryi, Kiniyis belliana, Kinixys erosa, Kinixys homeana, Kinixys spekii, Pelomedusa subrufa, Pelusios carinatus, Pelusios chapini, Pelusios gabonensis, Pelusios nanus, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Pelusios upembae, Pelusios williamsi, Trionyx triunguis.

RWANDA

Kinixys erosa, Pelomedusa subrufa, Pelusios rhodesianus.

SENEGAL

Cyclanorbis senegalensis, Geochelone sulcata, Kinixys belliana, Pelusios castaneus, Trionyx triunguis, Mauremys leprosa.

SIERRA LEONE

Kinixys belliana, Kinixys erosa, Pelusios castaneus, Trionyx triunguis.

SOMALIA

Geochelone pardalis, Geochelone sulcata, Kinixys belliana, Pelomedusa subrufa, Pelusios sinuatus, Trionyx triunguis, Stigmochelys pardalis.

S.AFRICA

Chersina angulata, Geochelone pardalis, Homopus areolatus, Homopus boulengeri, Homopus femoralis, Homopus signatus, Kinixys belliana, Kinixys natalensis, Kinixys spekii, Kinixys lobatsiana, Pelomedusa subrufa, Pelusios castanoides, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Psammobates geometricus, Psammobates oculifera, Psammobates tentorius, Stigmochelys pardalis.

SUDAN
Cyclanorbis elegans, Cyclanorbis senegalensis, Geochelone pardalis, Geochelone sulcata, Kinixys belliana, Pelomedusa subrufa, Pelusios adansonii, Pelusios gabonensis, Pelusios niger, Trionyx triunguis, Stigmochelys pardalis.
TANZANIA
Cycloderma frenatum, Geochelone pardalis, Kinixys belliana, Malacochersus tornieri, Pelomedusa subrufa, Pelusios castanoides, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Pelusios williamsi, Trionyx triunguis, Stigmochelys pardalis.
TOGO
Cyclanorbis elegans, Cyclanorbis senegalensis, Kinixys belliana, Pelomedusa subrufa, Pelusios castaneus.
TUNISIA
Emys orbicularis, Mauremys leprosa, Testudo graeca.
UGANDA
Geochelone pardalis, Kinixys belliana, Kinixys erosa, Pelomedusa subrufa, Pelusios chapini, Pelusios williamsi, Trionyx triunguis, Stigmochelys pardalis.
ZAMBIA
Geochelone pardalis, Kinixys belliana, Kinixys spekii, Pelomedusa subrufa, Pelusios bechuanicus, Pelusios nanus, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Stigmochelys pardalis.
ZIMBABWE
Geochelone pardalis, Kinixys belliana, Kinixys spekii, Pelomedusa subrufa, Pelusios bechuanicus, Pelusios rhodesianus, Pelusios sinuatus, Pelusios subniger, Stigmochelys pardalis.

Appendix 2. Summarized list of number of chelonian species occurring in each African country and the number of shared species with each of the neighboring countries.

Country	n. species	Countries and number of species shared in brackets
S. AFRICA	19	Mozambique (10), Botswana (9), Zimbabwe (8), Namibia (7),
RDC	16	Angola (9), Tanzania (7), Zambia (7), Uganda (6), Burundi (4), Sudan (4), Rwanda (3), Congo (3), CAR (2)
ANGOLA	13	RDC (8), Zambia (8), Namibia (5)
TANZANIA	12	Kenya (9), Mozambique (9), Malawi (9), RDC (7), Zambia (7), Uganda (6), Burundi (4), Rwanda (2)
BOTSWANA	11	S.Africa (10), Zambia (8), Zimbabwe (8), Nmibia (6)
MOZAMBIQUE	11	S.Africa (10), Tanzania (9), Malawi (9), Zambia (8), Zimbabwe (7)
NIGERIA	11	Chad (6), Cameroon (6), Benin (5), Niger (4)
SUDAN	11	Chad (7), Ethiopia (6), Eritrea (4), CAR (1), Egypt (1)
GHANA	10	Ivory Coast (6), Togo (5), Burkina Faso (3)
KENYA	10	Tanzania (9), Uganda (6), Somalia (6), Ethiopia (6), Sudan (5)
NAMIBIA	10	S.Africa (7), Botswana (6), Angola (5), Zambia (4)
ZAMBIA	10	Zimbabwe (9), Mozambique (8), Botswana (8), Angola (8), Malawi (7), RDC (/9, Tanzania (7), Namibia (4)
MALAWI	9	Mozambique (9), Tanzania (9), Zambia (7)
ZIMBABWE	9	Zambia (9), Mozambique (8), S.Africa (8), Botswana (8)
GABON	8	Cameroon (4), Congo (3), Eq. Guinea (3)
UGANDA	8	Kenya (6), Tanzania (6), RDC (6), Rwanda (2)
CAMEROON	7	Nigeria (6), RDC (6), Eq. Guinea (4), Gabon (4), Chad (3), CAR (2)
CHAD	7	Sudan (7), Nigeria (6), Niger (4), Cameroon (3), CAR (1)
ETHIOPIA	7	Somalia (7), Kenya (6), Sudan (6), Eritrea (4)

IVORY COAST	7	Ghana (6), Liberia (5), Mali (2), Burkina Faso (2), Guinea (1)
SOMALIA	7	Ethiopia (7), Kenya (6)
LIBERIA	6	Ivory Coast (5), Sierra Leone (3), Guinea (1)
MALI	6	Niger (4), Semegal (3), Burkina Faso (3), Ivory Coast (2), Mauritania (2), Algeria (1), Guinea (1)
SENEGAL	6	Mali (4), Mauritania (3), Guinea (2), Guinea Bissau (2)
BENIN	5	Nigeria (5), Togo (3), Burkina Faso (2), Niger (2)
LIBYA	5	Tunisia (2), Algeria (2), Egypt (2), Niger (1)
NIGER	5	Chad (4), Nigeria (4), Mali (4), Benin (2), Burkina Faso (1), Algeria (1), Libya (1)
TOGO	5	Ghana (5), Benin (3), Burkina Faso (3)
BURUNDI	4	RDC (4), Tanzania (4), Rwanda (2)
CONGO	4	RDC (3), Gabon (3), Cameroon (1), CAR (1)
ERITREA	4	Ethiopia (4), Sudan (4)
EQ. GUINEA	4	Cameroon (4), Gabon (3)
SIERRA LEONE	4	Liberia (3), Guinea (2)
ALGERIA	3	Tuinisia (3), Morocco (3), Libya (2), Niger (1), Mali (1)
BURKINA FASO	3	Mali (3), Togo (3), Ghana (3), Benin (2), Ivory Coast (2), Niger (1)
EGYPT	3	Libya (2), Sudan (1)
MOROCCO	3	Algeria (3), Mauritania (1)
MAURITANIA	3	Senegal (2), Mali (2), Algeria (1), Morocco (1)
RWANDA	3	RDC (3), Uganda (2), Tanzania (2), Burundi (2)
TUNISIA	3	Algeria (3), Libya (2)
GUINEA	2	Sierra Leone (2), Senegal (2), Mali (1), Ivory Coast (1), Liberia (1)
GUINEA BISSAU	2	Senegal (2)
CAR	2	Cameroon (2), RDC (2), Chad (1), Sudan (1), Congo (1)

Appendix 3. Body size (carapace length, mm) and main habitats for exclusively African chelonians. Symbols: (1) semidesert, (2) dry savannah (including Karoo), (3) open habitat (e.g., shrublands and plantation or agricultural land), (4) moist savannah, (5) Mediterranean shrublands (in both North Africa and South Africa), (6) tropical forest, and (7) swamp areas.

Species	Body size (mm)	Habitat
Geochelone sulcata	830	1,2,3
Chersina angulata	300	5
Homopus areolatus	160	5
Homopus femoralis	168	3
Homopus boulengeri	160	2
Homopus signatus	96	2
Homopus solus	114	1,2
Kinixys homeana	223	6,7
Kinixys erosa	400	6,7
Kinixys belliana	230	4
Kinixys spekii	200	2
Kinixys lobatsiana	200	2
Kinixys natalensis	160	2,3
Malacochersus tornieri	180	2
Psammobates tentorius	150	1,2
Psammobates geometricus	165	5
Psammobates oculifer	147	1,2
Stigmochelys pardalis	450	2,3
Trionyx triunguis	1200	4,6,7
Cycloderma aubryi	610	6,7
Cycloderma frenatum	560	4
Cyclanorbis elegans	600	4,6,7
Cyclanorbis senegalensis	500	4,6,7
Pelomedusa subrufa	325	2,3,4,6,7
Pelusios adansonii	220	6,7
Pelusios bechuanichus	330	7
Pelusios broadleyi	155	7
Pelusios carinatus	300	4,6,7
Pelusios castaneus	285	4,6,7
Pelusios castanoides	230	7
Pelusios chapini	380	4,6,7
Pelusios cupulatta	230	6,7
Pelusios gabonensis	330	6,7
Pelusios maranii	275	6,7
Pelusios nanus	120	4
Pelusios niger	350	4,6,7
Pelusios rhodesianus	255	7
Pelusios sinuatus	485	4,7

Pelusios subniger	200	3,4,7
Pelusios upembae	230	6,7
Pelusios williamsi	250	7